The Use of Steam Propagation Tests and Thermal Modeling to Develop In Situ Thermal Remediation Design Parameters

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Background/Objectives. At sites impacted by high concentrations of recalcitrant contaminants, including NAPLs, in situ thermal remediation (ISTR) has been successfully implemented to achieve site remedial goals. At sites where other remedial technologies are implemented, such as soil vapor extraction, air sparging and in situ chemical oxidation, pilot testing is routinely used to provide pertinent design criteria for full-scale implementation. In the case of ISTR, pilot testing has historically involved construction of robust treatment compounds to capture and treat mobilized contaminants. This has resulted in large capital costs for pilot tests and has led to minimal use of these tests in the design process for ISTR. At most ISTR sites, bench testing of small samples to determine some intrinsic properties such as soil resistivity and soil thermal conductivity are frequently used in conjunction with literature values to estimate design criteria, such as well spacing and heating rates for the full-scale project. In most of these cases, the key design parameters such as lithologic flow characteristics, hydraulic conductivity, and horizontal-to-vertical anisotropy have been assumed or estimated. This can lead to an over-reliance on conservative assumptions and factors of safety, which results in an over-design, inefficiency, and increased costs of the full-scale ISTR systems. An innovative design process developed to improve the design of steam-enhanced extraction (SEE) approaches will be presented. The process uses bench scale simulations using a steam generator, field implementation of steam propagation tests (SPT) and thermal modeling to develop full scale simulations and determine more accurate and site-specific design criteria to support more realistic designs of full scale SEE approaches. The results from three sites, where this process was used instead of large-scale pilot tests to develop design criteria for full-scale ISTR implementations, will be presented and discussed.

Approach/Activities. Soil and groundwater samples collected during conceptual site model investigations are analyzed for baseline parameters and prepared for bench-scale steam injection testing. Steam is injected into a test vessel containing site soils from the target treatment zone and temperature, pressure and contaminant mobilization are measured. The results are evaluated and used to determine the parameters of a field SPT. The SPT monitors the subsurface response of steam injection into a single steam injection well with temperature monitoring points (TMP) installed at varying distances in order to determine site-specific key design parameters. These include injection pressures and mass flow rates; steam front migration rates; conductivity of steam and water; anisotropy of vertical and horizontal conductivity and radius of influence. A site-specific three-dimensional, multiphase, non-isothermal steam injection heating model is then used to extrapolate the SPT data into a full-scale simulation.

Results/Lessons Learned. The SPT and thermal modeling process was implemented at two sites impacted by chlorinated solvents with DNAPL and at a former wood treating site impacted by creosote. The SPT process and follow-on thermal modeling was implemented at a fraction of cost of a large-scale pilot test. At one site in California, the results of a successfully completed, combined SEE and ERH project, confirmed that system performance matched the parameters predicted by the testing and modeling.